Proposed Test Procedure Modifications to Address Plug In Hybrid Electric Vehicles

California Air Resources Board
Mobile Source Control Division

Public Workshop
July 16, 2008

SCOPE

- Incorporate test procedures for PHEVs
  - Evaporative Emissions
  - Exhaust Emissions
- Aftermarket Parts
  - Off Vehicle Charge Capable Conversion Systems
- EV Charging Requirements

SCHEDULE

- Deadline for Comments July 22, 2008
- Staff Report Released September 5, 2008
- Board Hearing October 23, 2008

AGENDA

- Evaporative Emission Test Procedures
- Exhaust Emission Test Procedures
- Aftermarket Parts
- Charging Requirements

Evaporative/ORVR Test Procedures

Ron Haste

Evap Change Objectives

Update evap regs/test procedures (TPs) to reflect current Hybrid-Electric Vehicle (HEV) architectures:

- Traditional HEVs
  - Blended
  - Range extended
- Off-Vehicle Charge Capable HEVs
  - "Grid-Connected" HEVs
  - "Plug-In" HEVs ("PHEVs")
- Applicability
  - 2011 Model Year (MY)
  - Optional for 2009 & 2010 MYs

Current Evap Regulations

- LEV II Evap (1999)
  - Lower stds./Optional PZEVs
  - In-Use Verification Program
- Evap Tests
  - Running Loss (RL)
  - 3-day diurnal + high-temp. hot soak
  - Supplemental 2-day diurnal + hot soak
- On-Board Refueling Vapor Recovery (ORVR)
  - Adopted 1995
- Integrated & Non-Integrated Systems
  - 2-day test wavier allowed by “Evap Streamlining” (2006) for integrated systems only

Current Evap Applicability

- 2001 and subsequent MY gasoline-, LPG-, alcohol-fueled PC, LDT, MDV, HDV, HEV
- Exempt
  - Diesel vehicles
  - Dedicated CNG vehicles
  - HEV demonstrating “sealed” fuel systems

Main Purposes of Evap Testing

Demonstrate compliance w/applicable std.

- 3-day diurnal test
  - Ability to contain vapors for a 3-day period
- 2-day diurnal test
  - Ability to purge vapors under a short-drive event
- ORVR test
  - Ability to control vapors during a refueling event

HEV Evap Aspects

- Current Regs/TPs are Ok for most HEVs
  - Outdated “Sealed Fuel System” applicability
- HEVs have “Mutually Exclusive” objectives
  - Minimize IC engine operation (thus exh. emissions)
  - Maximize evap purge (via max. IC engine operation)
- PHEV Issues
  - Owner always “Plugs In”
  - TP State-of-Charge (SOC) reqmt. is not “worst-case”
  - Veh. preconditioning requires IC engine operation
  - What is “proper” canister preconditioning/loading?

Proposed Evap TP Changes

- Delete “Sealed Fuel System” applicability
- PHEV vehicle preconditioning
  - 2 UDDSs in Charge-Sustaining (CS) mode
  - Meet SOC reqmt (+/-1%)
- PHEV 2- & 3-day diurnal test sequences
  - Set SOC at max before Federal Test Procedure (FTP)
  - No SOC reqmt at end of FTP or RL test
  - Canister preconditioning/loading unchanged
- ARB cert confirmatory/in-use compliance tests
  - Test PHEVs w/SOC set at max/min/in-between

HEV ORVR Aspects

- Counter-balancing process
  - Refueling > loads canister w/vapors; replenishes fuel
  - IC engine use > depletes fuel in tank creating more vapor “head space” in tank; purges canister
- Current ORVR TP
  - Separate integrated & non-integrated test sequences
  - Encourage canister purging
  - Canister preconditioning/loading same as 2-day test
- PHEV ORVR Issues
  - Owner always “Plugs In”
  - What is “worst-case” for SOC?
  - Veh. preconditioning requires IC engine operation
  - What is “proper” canister preconditioning/loading?

Proposed ORVR TP Changes

- PHEV initial vehicle preconditioning
  - 2 UDDSs in CS mode/Meet SOC reqmt
- PHEV test sequence dyno driving
  - Integrated & non-integrated systems
  - Canister preconditioning/loading unchanged
- Integrated system
  - Set SOC at max before FTP/No SOC reqmt
- Non-integrated system
  - Set SOC at max before “drive downs”/No SOC reqmt
  - Allow lower SOC setting to save time
  - ARB confirmatory/in-use compliance tests w/SOC set at max/min/in-between

PHEV TP Canister Issues

What is “proper” canister loading?

- Integrated system
  - 1.5x working capacity (WC) > 3-day diurnal test
  - 2g breakthrough > 2-day diurnal & ORVR tests
- Non-integrated system
  - Refueling canister sees only refueling vapors
  - But if owner “always plugs in”
  - Vapors may reside in canister for an extended duration
  - Eventually breakthrough/bleed?
  - Keep current loading reqmts for 2-, 3-day & ORVR tests

Future PHEV Evap Considerations

- Uncertainties
  - "Always plugging in"?
  - Real-world PHEV duty cycles?
  - Canister purge characteristics?
  - Ultimate feasibility of integrated systems?
  - Reassess "worst-case" evap family test selection?
- Propose future technical review
  - When emissions are better understood
  - 3 years after initial MY phase-in

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Discussion

Summary of Modifications to the Off-Vehicle Charge Capable HEV Exhaust Emission Test Procedures

July 16, 2008 PHEV TP Public Workshop

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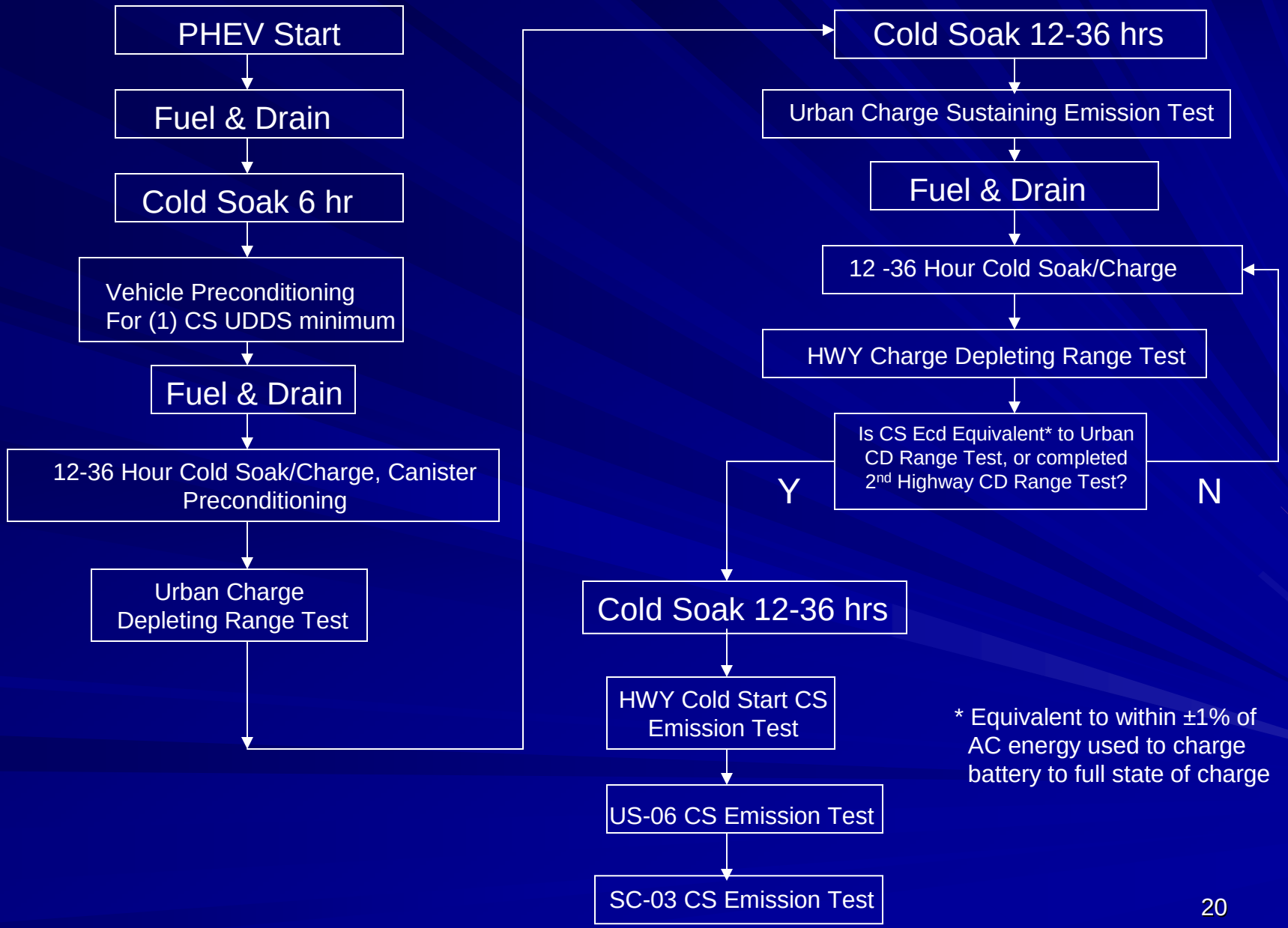
Definitions for Rcdc, Rcda

"Charge Depleting Actual Range or R_{cda}" means the distance travelled at which the state of charge is first equal to the average state of charge of the two consecutive UDDS tests that end the Urban Charge Depleting Range Test Procedure. This range shall be accurate to the nearest 0.1 miles. See section 10.9.

"Charge Depleting Cycle Range or R_{cdc}" means the distance traveled on the Urban or Highway Charge Depleting Procedure up to the test cycle prior to where the state of charge is above the lower bound state of charge tolerance for one test cycle. This range will appear as the sum of a discrete number of test cycle distances. This range shall be accurate to the nearest 0.1 miles. See section 10.8.

Proposed PHEV Exhaust Emissions Test Sequence



* Equivalent to within ±1% of AC energy used to charge battery to full state of charge

Urban Charge Depleting Range Test Example of Off Board Charge Capable HEV with All-Electric Range and Blended Operation

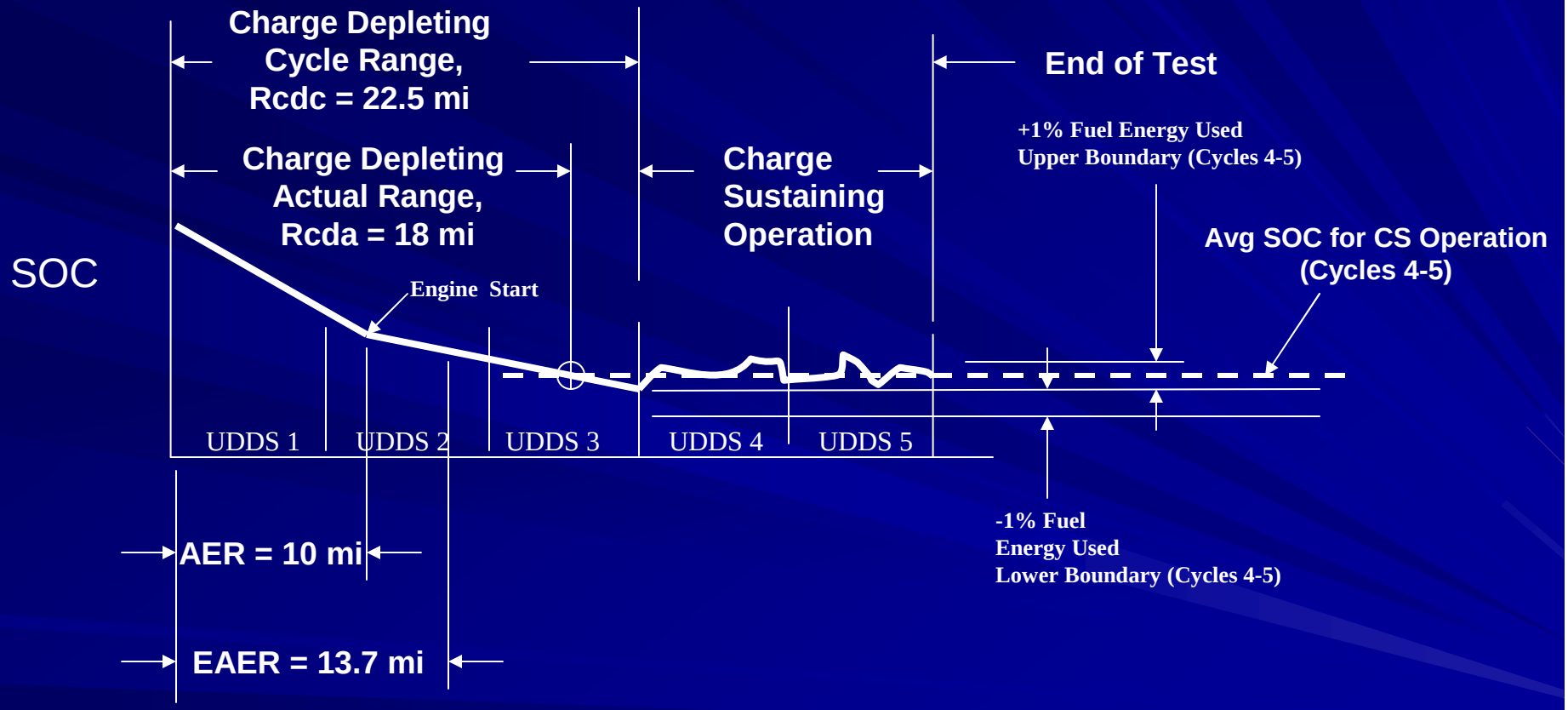
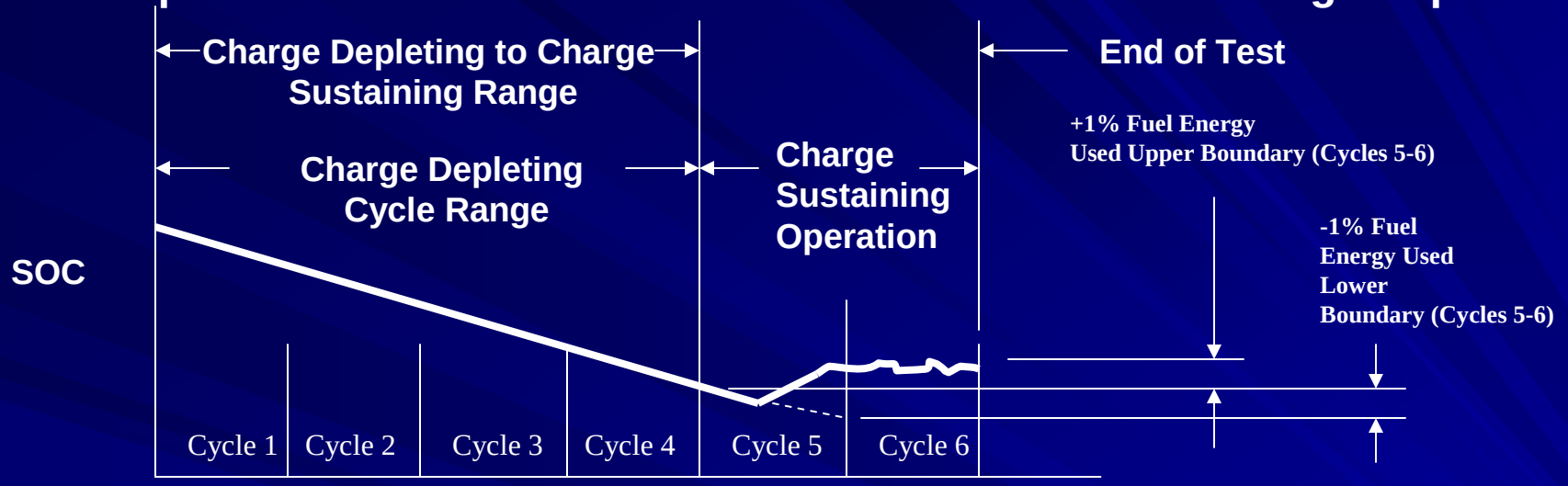


Figure 1

Example of Urban End of Test Conditions for Off Board Charge Capable HEV



Example of Urban End of Test Conditions for Off Board Charge Capable HEV with Transitional Range

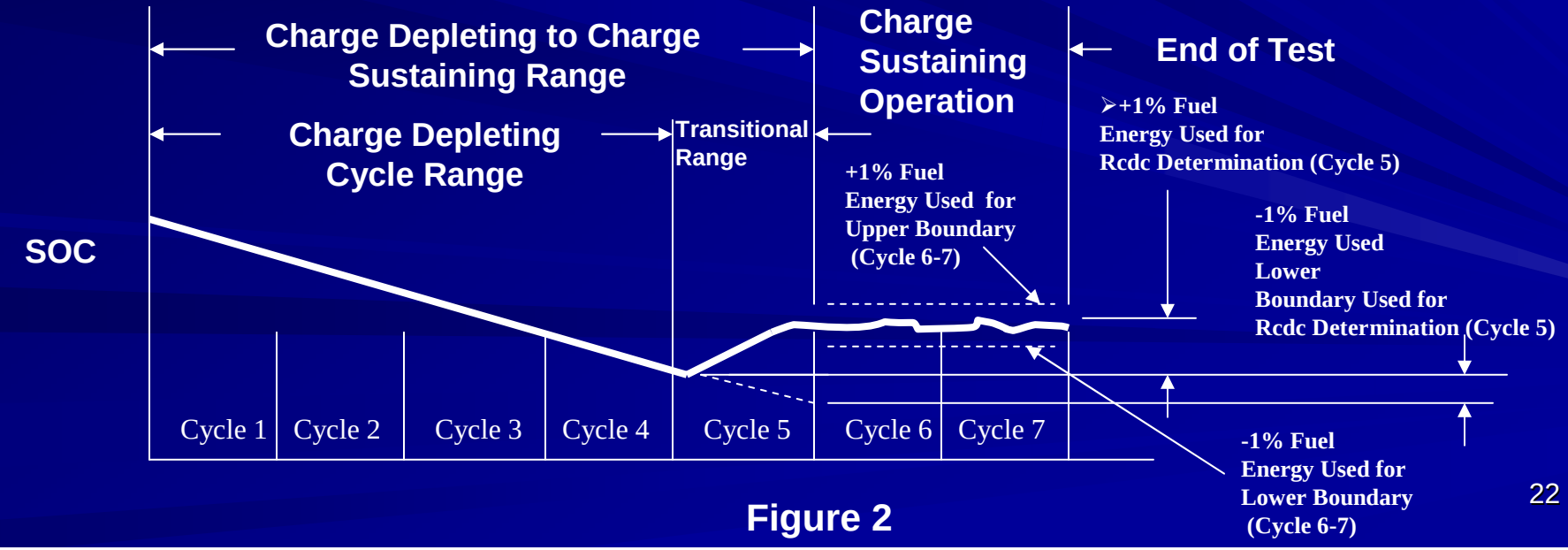


Figure 2

SOC Net Tolerances

Propose to keep SOC Net Tolerances at 1% (instead of TBD) for 2 UDDS (instead of 1 UDDS) test to establish charge sustaining urban operation and test validation for charge sustaining tests.

- Consistent with current SAE J1711 and ARB Test Procedures in place for almost 10 years.
- Will consider changes when more data are available.

Vsystem Definition

Vsystem = Average charge sustaining battery DC bus voltage (open circuit). This value shall be submitted for testing purposes, and it shall be subject to confirmation by the Air Resources Board.

DC Energy Measurement

Retain section 3.1d:

(d) DC energy required to fully charge the battery after a charge depleting or charge sustaining test from the point where electricity is introduced from the battery charger to the battery; and

- Required for Electric Vehicles and previous PHEVs.
- Allows calculation of DC/AC as well as DC/DC efficiency.
- Allows isolation of battery charge current without ancillary loads.
- No additional equipment required to monitor.

Energy Measurement Definition

DC Energy = $\int v(t) * i(t)\, dt$

Opinion from Tom Gage, President & CEO of AC Propulsion:

Energy calculation based on actual voltage and current will offer “the most accurate indication of energy - anything else is an estimate”.

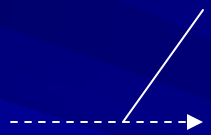
Similar opinion shared by Andrew Simpson, Tesla Motors.

Consistency with ARB’s current electric vehicle DC energy measurement requirements.

Reduced Charging Requirement

Only one required charge for PHEV testing if AC Energy to fully recharge is within ± 1% between the Urban and Highway CD Range tests, or the AC Energy to fully recharge for Urban CD Range test > AC Energy to fully recharge for the Highway CD Range test. Reduces test burden by one day.

Day 1: Urban CD Range test
Cold Soak
Day 2: Urban CS Emission test
Charge
Day 3: Highway CD Range test
Cold Soak
Day 4: Highway CS Emission test
US06 CS Emission test
SC03 CS Emission test



(Without Charge Options)

Day 3: Highway CD Range test
Cold Soak/Charge
Day 4: Highway CD Range test
Cold Soak
Day 5: Highway CS Emission test
US06 CS Emission test
SC03 CS Emission test

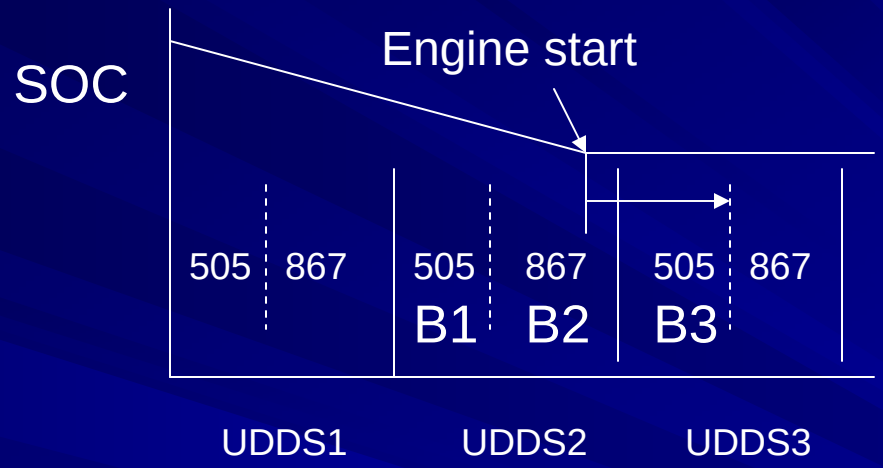
Optional 3 Hour Charge Window

Charge is allowed within three hours of completing Urban or Highway charge sustaining test if data is shown that AC energy for a 3 hour charge is within ± 1% of a 1 hour charge.

50 F and 20 F Cold Test Concepts

- Retains most requirements of current 3 Bag FTP cold tests.
- Require CD or CS 50 F test based on worst case NMHC +NOx CD or CS test emissions at 68 F – 86 F.
- Require CD or CS 20 F test based on worst case CO CD or CS test emissions at 68 F– 86 F.
- CD Test would use the Continuous Urban Driving Schedule until engine starts and 3 bags samples (1 UDDS + hot 505) are obtained. If engine starts in bag 2, bag 1 emissions will be zero.
- CS test would be same as current 3 bag cold FTP test for non-plug in HEV.
- SOC Net Tolerances not required for both CS and CD, 20 F and 50 F tests.

Example of 3 Phase Charge Depleting Cold Test



Y (g/mi) = .43 X (~~B1~~ 0 + B2) / (D1 +D2) + .57 X (B2 + B3) / (D2 + D3)

Based on theory that the majority of cold start emissions occur within the first few minutes after engine start.

Highway, US06, SC03 Highlights

- Highway NOx emissions evaluated during Highway Charge Sustaining Emission test only.
- No canister preconditioning requirement for Highway tests.
- Retained 3 HFEDS tests for the Charge Sustaining Emissions test with NOx evaluated on the third HFEDS. Since this is a cold start test, the vehicle may not be fully stabilized after performing only one HFEDS prep according to data from Argonne National Laboratory.
- Reduced the number of maximum number of validation tests in order to meet SOC criteria for the US06 and SC03 tests from 3 to 2 per AAM request.

Equivalent All-Electric Range Calculation

- Will consider new equations based on g/mi instead of g per phase to address slight variations in driving distances from test to test and to simplify calculations.
- May result in a very small change to final result compared to old method, although the result may be the same for the final EAER calculation since both are rounded to the nearest 0.1 mile.

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Discussion

AFTERMARKET PARTS

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Objectives

- Address off-vehicle charge capable (OVCC) kits
  - Regulation language
  - Applicability
  - Certification & Installation Procedure

Regulation

- Applicability
  - Applies to OVCC kits
  - For installation on OEM hybrid electric vehicles

Certification & Installation Procedure

- Emission Testing
- Durability
- Warranty
- In Use Testing

Emission Test Procedures

- OVCC emission levels compared to original HEV emission standards
  - Hybrid Exhaust sections F & G
  - Evaporative procedure

Durability Testing

- Similar to other retrofit kit certification
- OVCC must be durable for useful life of converted vehicle
- Durability demonstration may be performed through bench aging or mileage accumulation

Warranty

- Provided for same period as OEM
  - 3 years / 50,000 miles (low cost items)
  - 7 years / 70,000 miles (high cost items)
  - 10 years / 150,000 miles (PZEV)
- Requirements for both manufacturers and installers

In Use Testing

- Kit manufacturer must provide up to five in-use OVCC converted vehicles/year for testing
  - ARB or other designated lab perform tests
  - Compare to original certification standards
  - Testing costs covered by ARB unless vehicles fail to meet emission standards

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Discussion

EV/PHEV CHARGING REQUIREMENTS

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Outline

- 2001 Requirement
- Current Considerations & Issues
- Proposed Modifications

2001: Conductive VS Inductive

- Prior to 2001, there were (too) many competing EV charging connection types
- Inductive connection advocates eventually admitted:
  - that on-vehicle weight savings were negligible,
  - safety was equivalent, but
  - “perceived safety” and enhanced profit were also considerations

2001: EV Charging Infrastructure

- Unintended consequences of moving the charger “off-vehicle”…it gets moved back on.

1990's: EV Charging Infrastructure: Connection Types

Mfg	Application	Type	Charger Location
Yazaki	RAV4EV REV1	Conductive	On-vehicle
Avcon	EV+, Ford, Honda	Conductive	On-vehicle
Small Paddle Inductive	GM, RAV4EV REV2, e.com	Inductive	Off-vehicle
Large Paddle Inductive	GM, Nissan	Inductive	Off-vehicle
ODU	Chrysler	Conductive	Off-vehicle
Level I (1.4 kW)	Toyota e.com	Conductive	On-vehicle
ARB 2006+ (Required for Credit)	**All**	**Conductive, SAE J1772 Compliant**	**On-vehicle**

2001: EV Charging Infrastructure

- ARB held workshops & review of the technical differences between conductive and inductive connection standards
- In 2001 ARB adopted requirements for all manufacturers to use the simpler conductive charging inlet port on EVs and PHEVs per SAE J1772

2007-2008: SAE Currently Revising the J1772 Standard

- SAE is converging on a single physical interface for the inlet. Manufacturer identified: Yazaki
  - Potentially 2 physically compatible versions: high current and low current
  - May also become the standard in Japan
- Protocol may be very similar to earlier J1772
  - May also be used in Europe (handshake protocol only- not the connection)
  - Potentially backwards compatible with older charging stations (TBD)

2008: Current Considerations & Issues

- Existing regulation references the soon-to-be obsolete SAE J1772 RP
  - (with Avcon connector)
- Level 1 definition challenges within the current regulation

2008: Existing ARB EV Charging Requirements

§ 1962.1. Electric Vehicle Charging Requirements.

(a) *Applicability.* This section applies to (1) all battery electric vehicles that qualify for 1.0 or greater ZEV credit under section 1962, and (2) all hybrid electric vehicles that are capable of being recharged by a battery charger that transfers energy from the electricity grid to the vehicle for purposes of recharging the vehicle traction battery, **other than battery electric vehicles and hybrid electric vehicles that are only capable of Level 1 charging.**

2008: Existing ARB EV Charging Requirements

(b) *Definitions.*

(1) The definitions in section 1962 apply to this section.

(2) "Level 1 charging" means a charging method that allows an electric vehicle or hybrid electric vehicle to be charged by having its charger connected to the most common grounded receptacle (NEMA 5-15R). A vehicle that is only capable of Level 1 charging is one that is charged by an on-board or off-board charger capable of accepting energy from the existing AC supply network. The maximum power is 12 amps, with a branch circuit rating of 15 amps, and continuous power of 1.44 kilowatts.

2008: Existing ARB EV Charging Requirements

(c) *Requirements.* Beginning with the 2006 model year, all vehicles identified in subsection (a) must be equipped with a conductive charger inlet port which meets all the specifications contained in Society of Automotive Engineers (SAE) Surface Vehicle Recommended Practice SAE J1772 REV NOV 2001, SAE Electric Vehicle Conductive Charge Coupler, which is incorporated herein by reference. **All such vehicles must be equipped with an on-board charger with a minimum output of 3.3 kilovolt amps.**

2008: Proposed Modifications

- Update the SAE J1772 reference
- Delete Level 1 definition, and simplify the requirement by substituting a 4 hour maximum charge time

Charge Time

Vehicle	UDDS Range (miles)	Usable Energy (kWhr)	Charge time with charger power of: (hours)	
			1.4 kW	3.3 kW
PHEV 10	10	2	1.4	0.4
PHEV 20	20	4	2.9	0.9
PHEV 25	25	5	3.6	1.1
PHEV 40	40	8	5.7	1.7
Type I CityEV	50	10	7.1	2.2
Type I.5 CityEV	75	15	10.7	3.2
Type II EV	100	20	14.3	4.3

2008: Proposed Modifications

(c) Requirements. Beginning with the 2006 2009 model year, all vehicles identified in subsection (a) must be equipped with a conductive charger inlet port which meets all the specifications contained in Society of Automotive Engineers (SAE) Surface Vehicle Recommended Practice SAE J1772 REV NOV 2001 XXX 2009, SAE Electric Vehicle Conductive Charger Coupler, which is incorporated herein by reference. All such vehicles must be equipped with an on-board charger with a minimum output of 3.3 kilovolt amps or an on-board charger with sufficient power capability to restore 95% of ARB certification UDDS range or Equivalent All-Electric Range in 4 hours or less.

2008: Other Considerations & Issues

- SAE may not be done with J1772 this year
- Some early model PHEVs will be “conversions” (not ground-up designs) and may not yet be able to accommodate larger on-board chargers
  - Possible Solutions:
    - Delay 4 hr implementation (until 2012 or 2015), or
    - Start with 6 hr charge requirement, and transition to 4 hr in 2012 or 2015

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Discussion